Spring 5-4-2019

Neurological Balance Assessment to Screen Fall Risk: A Methodological Study

Yiwen Xia
University of Nebraska Medical Center

NEUROLOGICAL BALANCE ASSESSMENT TO SCREEN FALL RISK: A METHODOLOGICAL STUDY

by

Yiwen Xia

A THESIS

Presented to the Faculty of
the University of Nebraska Graduate College
in Partial Fulfillment of the Requirements
for the Degree of Master of Science

Medical Sciences Interdepartmental Area
Graduate Program
(Physical Therapy)

Under the Supervision of Professor Ka-Chun (Joseph) Siu

University of Nebraska Medical Center
Omaha, Nebraska

April, 2019

Advisory Committee:
Diego Torres-Russotto, M.D.   Danish Bhatti, M.D.

Acknowledgements

I would first like to thank my thesis advisor, Professor Siu of Division of Physical Therapy Education in College of Allied Health Professions, UNMC. He offered me countless ideas and comments on the study design, data analyses and manuscript.

I would also like to thank Drs. Torres and Bhatti of Department of Neurological Science, UNMC. They introduced orthostatic tremor to me and generously shared the raw data of orthostatic tremor study for my research. Dr. Torres offered lots of clinical expertise to facilitate my understanding of balance and balance tests.

Finally, I must express my profound gratitude to my parents and friends for their continuous support and encouragement throughout my study. It is not easy to pursue master and DPT degrees at the same time. This accomplishment would not have been possible without them. Thank you.

NEUROLOGICAL BALANCE ASSESSMENT TO SCREEN FALL RISK: A METHODOLOGICAL STUDY

Yiwen Xia, M.S.

University of Nebraska Medical Center, 2019

Advisor: Ka-Chun (Joseph) Siu, Ph.D.

According to the World Health Organization, falls are the second leading cause of accidental or unintentional injury deaths worldwide. The medical cost on fall related injuries becomes a huge financial burden. In order to prevent falls and fall related injuries, fall risk assessment becomes a routine practice for healthcare providers. In most clinics, practitioners conduct a quick neurological balance assessment in the room or along the hallway to determine abnormal gait pattern, indicating increased risk of falls. However, the validity of such subjective assessment is questionable. The purpose of this study was to identify a single feasible neurological balance task or a combination of balance tasks which would have the equivalent utilization to screen fall risk as the Berg Balance Scale. I found that single task including stance base, stance with feet apart eyes closed, stance with feet close eyes open, stance with feet close eyes closed, gait in Brief Ataxia Rating Scale, pull test and unipodal jump can screen fall risk. Combined tasks increased the specificity of fall risk screening. The combination of unipodal jump OR Pull test and the combination of unipodal jump OR arising from chair have balanced sensitivity and specificity to screen fall risk. In conclusion, this study suggests pull test and unipodal jump as the best two clinical bedside tasks to screen fall risk.

Table of Contents

CHAPTER 1: INTRODUCTION

1. Background of falls

According to the World Health Organization (WHO), falls are the second leading cause of accidental or unintentional injury deaths worldwide. Adults older than 65 years ago suffer the greatest number of fatal falls. In WHO's risk factor model for falls in older age, fall and fall-related injuries are associated with biological risk factors, behavioral risk factors, environmental risk factors and socioeconomic risk factors.[1] Some of risk factors are changeable, such as environmental and behavioral risk factors, including slippery floor, loose rug, lack of physical activity, obesity and substance abuse, while some cannot be changed, such as age and chronic disease. According to the United States Centers for Disease Control and Prevention, one in four of Americans aged over 65 years old falls each year and every 19 minutes, an older adult dies from a fall. Every year, more than 2.8 million injuries treated in emergency departments are caused by falls in the United States.[2] Moreover, falls may lead to traumatic brain injuries, causing irreversible impairments, such as cognition deficit, aphasia, weakness, which suddenly and drastically impact their family and community. The medical cost on fall related injuries are dramatic all over the world, becoming a huge financial burden as well as a massive public health problem.

In order to prevent falls and fall related injuries, fall risk assessment has become a routine for most of the healthcare providers, including doctors, nurses, physical therapists, pharmacists and others. Practitioners use various fall risk assessment tools based on their professional background and expertise. The simplest assessment can be an interview question, “Have you had any falls in the past six months?”, while the experts, such as practitioners in fall clinic may go through several balance tasks with patients to evaluate their balance performance.

2. Background of objective clinical tests/scales to predict fall risk

Objective clinical tests and scales

In the medical field, clinical practitioners use validated, reliable objective tests/scales as often as possible to fulfill standardized practice and evidence-based practice. An objective test usually contains one task, while an objective scale consists of two or more tasks. Designers of objective clinical tests/scales usually publish the instruction and standardized form on professional journals or sell the assessment kit to the practitioners per request. The instruction may include applicable population, equipment/device/space requirement, estimated cost of time, and etc. The standardized form clearly states the setting of the test, amount of trials, verbal instructions, detailed grading criteria and interpretation of result based on designer's validation study. Once a novel assessment tool publishes, researchers and clinicians throughout the world translate it into local language and conduct it in various studies with different samples or patient populations. Some researchers may be adventurous enough to apply the novel assessment tool into unexplored population, so as to extend the applicable population of the assessment tool.

Validity and statistical characteristics

The validity of a test is defined as its capability to differentiate patient with and without a certain disease. There are face validity, content validity, criterion-related validity and construct validity. Criterion-related validity is also known as concurrent validity. Researchers compare the new tool to the gold standard scale to determine the validity. Validity consists of two components, sensitivity and specificity. The sensitivity of the test is defined as the ability to identify correctly those who have the disease. The specificity is defined as the ability of the test to identify correctly those who do not have the disease.[3] Positive predictive value (PPV) is defined as the proportion of patients who test positive actually have the disease. Negative predictive value (NPV) is defined as the proportion of patients who test negative actually have no disease. Unlike sensitivity and specificity, predictive values are related to disease prevalence. Higher prevalence of a certain disease leads to higher PPV. Likelihood ratios are one of the best measures to reflect accuracy of a diagnostic tool, although they are seldom used because of difficulty in interpreting results.[4] The likelihood ratio of any clinical finding is the probability of the finding in patients with disease divided by the probability of the same finding in patients without disease. Positive likelihood ratio (PLR) is the likelihood ratio of a positive finding.

Table 1: Descriptions of sensitivity, specificity, PPV, NPV, PLR and NLR

Test results	disease	No disease
positive	True positive(TP) = have disease and have a positive result	False positive(FP) = no disease but have a positive result
negative	False negative(FN) = have disease but have a negative result	True negative(TN) = no disease and have a negative result

Sensitivity=TP/(TP+FN), Specificity=TN/(TN+FP), PPV=TP/(TP+FP), NPV=TN/(TN+FN), PLR=sensitivity/(1-specificity), NLR=(1-sensitivity)/specificity.

Negative likelihood ratio (NLR) is the likelihood ratio of a negative finding of a diagnostic tool. Likelihood ratios range from 0 to infinity. Values between 0 to 1 indicate the decline of probability of disease, while values greater than 1 support appearance of disease. Value of 1 means no diagnostic value. For values between 0 to 1, the lower indicates the less likely a disease appears. For values greater than 1, the higher implies the higher probability of disease. For example, if a patient has a negative result in a test whose NLR equals to 0.1, the probability of illness decreases by 45%. If a patient has a positive result in a test whose PLR equals to 10, patient’s probability of illness increases by 45%. Table 1 defines the sensitivity, specificity, PPV, NPV, PLR and NLR.

Validated functional tests/scales

To screen patients' balance deficits and fall risks, clinical practitioners currently use various functional tests and scales based on their expertise and resource, such as Berg Balance Scale (BBS), functional reach test (FRT), Dynamic Gait Index (DGI), Functional Gait Assessment (FGA), Timed up and go (TUG) test, etc. Those standardized scale or test has been validated by designers and following researchers in different population. They are valid and reliable to assess fall risk.

Berg et al. firstly developed and validated BBS in 1992.[5,6] The BBS is moderately correlated with caregiver ratings, self-ratings and laboratory measures of sway; strongly correlated with functional and motor performance in stroke patients.[5] Also, it can predict the occurrence of multiple falls among elderly residents. There are 14 tasks to assess static and functional balance abilities, which are essential to complete activities of daily living (ADLs). The tasks are unsupported sitting, unsupported standing, standing with eyes closed, standing with feet together, standing on one foot, standing and turning to look behind, retrieving object from floor, tandem standing, reaching forward, sitting to standing, standing to sit, transfer, turning 360 degrees and stool stepping. For each task, the rater will score from 0 to 4 based on observation and measurement. The maximum of score is 56. Equipment involved is easily accessed in a clinical setting, including a stopwatch, a ruler, a standard height chair, a standard stair step. The developer suggested a cutoff score of 45 to distinguish fallers and non-fallers. Lajoie Y and Gallagher SP conducted the BBS in over 100 elderly and found 82.5% sensitivity to identify people who did fall and 93% specificity to identify people who did not fall by the used cutoff point of 45.[7] For reevaluation, a minimal detectable change in score of the BBS is ± 6 point from Stevenson et al.[8] See appendix A.

The unified Parkinson's disease rating scale (UPDRS) was originally developed in the 1980s and the Movement Disorder Society (MDS) published a revision of the scale in 2008 to reflect current scientific developments and decrease ambiguity of some questions.[9] There are four parts in the MDS-UPDRS and it takes up to 30-minute rater involvement time, in addition to patient/caregiver questionnaire input time. The four parts of scale consist of non-motor experience of daily living, motor experience of daily living, motor examination and motor complications. The multi-center clinimetric testing program revealed that this scale has strong concurrent validity as the original one and it is statistically consistent and clinically meaningful.[9] It is a lengthy but thorough assessment tool for patients who are highly suspected of balance deficits, especially patients with Parkinsonism symptoms.

Duncan PW et al. proposed FRT as a new clinical measure of balance in 1990.[10] They found it as a portable, inexpensive, reliable, precise and a reasonable clinical approximator of the margin of stability. The only equipment needed is a yardstick. The test instruction is to "reach as far as you can without taking a step" with fist and arm in 90° of shoulder flexion. (See Figure 1) Age and height are major affecting factor of reaching distance. To validate, Duncan et al. compared FRT versus Center of Pressure Excursion (COPE) on reliability and precision. They found FRT correlated with COPE (Pearson r=.71) and is precise (coefficient of variation=2.5%) and stable (intraclass correlation coefficient across days =.81). They also validated this test in the elderly population and found that scores of 6 inches or lower showed a significant increase in fall risk for older adults.[11] In clinics, we

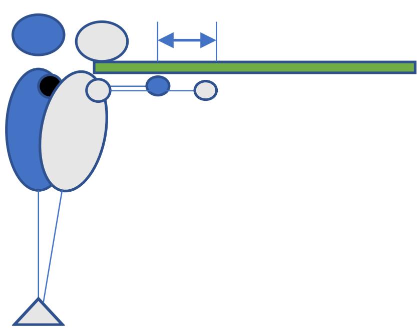

Figure 1: Functional Reach Test

currently use 10 inches as the cutoff to determine fall risk. The FRT is also a part of the BBS.

DGI is a performance-based tool to quantify dynamic balance ability, developed by Shumway-Cook and Woollacott.[12] This test has more vestibular components in tasks, such as gait with horizontal or vertical head turns. There are eight tasks in this test with a 4-point ordinal scoring scale for each task. The tasks are gait on level surface, change in gait speed, gait with horizontal head turns, gait with vertical head turns, gait and pivot turn, step over obstacle, step around obstacle, steps. A higher score indicates a better level of function. The test has excellent interrater reliability and test-retest reliability reported by the developer. But Wrisley et al. raised concerns of lack in decision-making rules for scoring[13] Chiu et al. used this test in 84 community-dwelling, male veterans with balance problems and study results supported the application for community-dwelling older population.[14] in clinical practice, scores of 19 or less have been related to falls in community living elderly adults and individuals with vestibular disorder.

The FGA is developed by Wrisley et al. and to revise DGI. It consists seven tasks from the DGI (deleted step around obstacle) and adds three new tasks including gait with narrow base of support, ambulate backwards and gait with eyes closed. Compared to DGI, it is a broad composite assessment of gait and dynamic stability. There are 10 tasks in total with a maximum score of 30. Developers suggested a score of 22 on the FGA as a cutoff to effectively predict falls in community-dwelling older adults.[15]

Timed Up & Go (TUG) test is a quick screening measure of dynamic balance and mobility. The test involves sit to stand, ambulation and turn. The patient is instructed to stand up from a standard chair, walk at a comfortable speed for 3 meters and go back to sit. Shumway-Cook et al. suggested a cutoff score of 13.5 seconds for community dwelling adults.[16] Whitney et al. reported cutoff score of 15 seconds for older adults already attending a fall clinic.[17] This test has an inevitable ceiling effect to patients with high daily function.

3. Challenge of clinical practitioners and neurological balance assessment

For physical therapists, they are trained to conduct a variety of balance tests/scales in their clinical practices so that they can select the most proper assessment tool to their patients. However, many physicians or primary care providers have not received enough training on many balance tests/scales, in addition, those clinical tests are too long to complete in a 15-minutes office visit. Moreover, they may not have access to those validated tests/scales. The clinical environment may not allow them to conduct a standardized test. Instead, most of the clinical practitioners will conduct a quick, neurological balance assessment in their clinics or hallway. For instance, they will observe patient's sit to stand, transfer, gait pattern, stance base, stance with feet apart eyes closed, stance with feet close eyes open, stance with feet close eyes open, stance with feet close eyes closed, line of ambulation, pause after turning, tip toe walking, heel walking, tandem walking, pull test and unipodal jump.

Pull test is commonly used in the neurological clinics to assess postural stability. It is also a task in the part 3 of MDS-UPDRS. The examiner stands behind patient and conducts a quick, forceful pull on shoulders, observing the number of steps patient takes to catch balance or loss of balance.[9] Before the test, examiners are required to verbally describe the test and warn patient before the pull. The subjective nature of this test is inevitable because there is not a qualitative definition of "quick, forceful" pull. Munhoz et al. conducted a study to evaluate the pull test technique.[18] They assessed 66 patients by 25 examiners and only 9% of examinations were error-free. The major error happened in strength and briskness of the pull. From previous studies, pull test correlates poorly with important clinical end points, such as falls.[19-21]

In addition, the choice of assessment items is based on practitioners' personal preference, clinical experience and patient's tolerance. They may or may not perform all the tasks mentioned above depending on the patient's age and previous level of function. The principal characters of screening tasks are quick, no equipment/space requirement, simple instruction, safe and easy-to-interpret. But the validity of such subjective, flexible assessment is questionable. Every practitioner has his/her personal understanding of abnormal gait. Sometimes, the balance decline can be very minimal and hard to detect. When a practitioner has several positive results and several negative results in hand, s/he will be confused and wondering which clinical balance test is the most reliable. Therefore, my study focuses on the validity of neurological balance assessment. The purpose of this study is to identify a feasible, valid neurological clinical task or a combination of clinical tasks which have the equivalent capability to screen fall risk as BBS.

4. Background of primary orthostatic tremor

Primary orthostatic tremor (POT) is a very rare diagnosis and has been under-studied due to low prevalence in the general population. The pathophysiology of POT is unknown. The first case study of orthostatic tremor was published in 1984 by Dr. Heilman. He described three patients with an orthostatic tremor that mainly involved in lower extremities and trunk and symptoms disappeared as they walked, sat or lay down.[22] In 2018, consensus statement on the classification of tremors from the task force on tremor of the International Parkinson and Movement Disorder Society described POT as "a generalized high-frequency (13-18 Hz) isolated tremor syndrome that occurs when standing. Confirmation of the tremor frequency is needed, typically with an electromyography(EMG)".[23] Patients with POT present with a severe feeling of unsteadiness as well as high-frequency leg tremor only in standing still position.[24-26] Many patients report that they are about to fall, but actually, they rarely fall.[25] The severe feeling of unsteadiness disappears on walking, sitting, lying down or even leaning on something.[27] The causation between leg tremor and feeling of unsteadiness is unknown.[28-31] Some researchers found cerebellum plays an important role in long-term disease progression.[32] Orthostatic tremor can also be one of the symptoms in other neurological diseases, such as Parkinson's Disease. In the clinical guideline, they are suggested to be classified as secondary orthostatic tremor. The UNMC study project has found that patients with POT present abnormal results in most functional balance tests, which is disproportionate to their self-report fall history.[33] Thus, it is unsure whether a patient with POT has substantial fall risk since they rarely fall. In this study, 45 out of 65 subjects have either EMG-diagnosed POT or have secondary orthostatic tremor, such as patients with Parkinson's disease.

CHAPTER 2: METHODS

Study subjects

This study was a secondary analysis. All the raw data came from an ongoing orthostatic tremor study project in the University of Nebraska Medical Center (UNMC). The study subjects included patients with orthostatic tremor and their spouses. The study had been approved by the UNMC Institutional Review Board. Consents were obtained by phone call before patients traveled to UNMC. Researchers discussed with the patients about inclusion and exclusion criteria by phone call, confirming that the subject was a qualified candidate before they booked the trip. A signed consent was obtained at the beginning of study visit. Diagnostic, inclusion, exclusion criteria are listed in table 2.

Table 2: recruitment criteria

Diagnostic criteria	*Two of the three must be present.* 1. Sensation of unsteadiness on standing upright without support that resolves/improves with minimal support. 2. Sensation of unsteadiness improves/resolves with walking forward and on sitting and lying down. 3. EMG documented tremor of weight bearing limb that goes away with walking. *Additional evidence, supportive but not required:* 1. Lower extremity visible, palpable, auscultated or subjective tremor on standing upright without support. 2. Upper extremity tremors on weight bearing. 3. Tremor in fast frequency range of 8 Hz and above with slow range being 8-12 Hz and fast range being 13 Hz and above. 4. EMG documentation of synchronicity between different muscles of same limb and contralateral limbs. 5. Resolution of tremor on EMG during swing phase of gait during walking and on sitting and/or lying down.
Inclusion criteria for subjects with OT	1. Age: 18 years or above. No upper limit is posed. 2. Participant carries a diagnosis of OT. 3. Patient is able to provide informed consent.
Inclusion criteria for spouse	1. Age: 18 years or above. No upper limit is posed.

	2. Participant does not carry a diagnosis of OT. 3. Patient is able to provide informed consent. No diagnosis of dementia.
Exclusion criteria for all subjects	1. Previous known history of vestibular injury or other causes of significant imbalance (beyond OT). 2. High fall risk as deemed by caregiver or physician. 3. Unable to complete the 2 hours of evaluations.

Study process and data collection

Subjects went through two examination stations. First, a neurologist completed a thorough clinical evaluation in movement disorder clinic, including UPDRS, ataxia evaluation (Brief Ataxia Rating Scale, BARS) and clinical balance/gait assessment. (See table 3 for balance/gait assessment items. See Appendix C for neurological examination worksheet.) Then, a formal, functional balance assessment was performed by a physical therapist who is fully trained and experienced in conducting functional tests/scales. There were several physical therapists participating in this project but each patient underwent the full assessment by the same physical therapist in a uniform sequence. All physical therapists were blinded, not aware of patient's diagnosis.

Table 3: Clinical balance/gait assessment

Items	Possible Results
Truncal sway during sit to stand transfer	Present/absent
Arising from chair (from MDS-UPDRS)*	0/1/2/3/4
Stance base	Normal/wide
Stance with feet apart, eyes closed	Normal/abnormal
Stance with feet close, eyes open	Normal/abnormal
Stance with feet close, eyes closed	Normal/abnormal
Line of ambulation	Straight/wavy
Arm swing in walking	Present/absent
Pause after turning	Present/absent
Tip toe walking	Normal/abnormal
Heel walking	Normal/abnormal
Tandem walking	Normal/abnormal
Gait (from BARS)*	0/1/2/3/4/5/6/7/8
Pull test (from UPDRS)*	0/1/2/3/4
Unipodal hop (up to 10)	L: R:

Patients' test results were manually imported from handwritten documentation into the Research Electronic Data Capture (REDCap) platform and exported to Microsoft Excel worksheets for further data analysis.

Data analysis

SPSS Statistics software version 12 (IBM, Armonk, New York) was used for data analysis. All data were imported into SPSS as Microsoft Excel worksheet, which was downloaded from the REDCap platform. BBS was chosen as the gold standard in this study because it not only covers static and dynamic balance but also has been well validated and recognized by previous studies. In many previous studies, researchers used BBS as criterion or one of the criteria to complete the concurrent validation.[34-40] BBS score of 45/56 was used as cutoff, which is commonly used in the general population.[5,7] Subjects scored ≤45 will be classified into fall risk group. All the concurrent validity of each balance task were calculated with 2x2 table method. For those tasks which have 3 or more grading levels, different cutoff points were selected in one task. Combined tasks analysis was completed after single task analysis. The candidates for combined task analysis were selected based on their validity results in single task analysis. Only the tasks with either sensitivity or specificity ≥95% would be considered for combined tasks analysis.

CHAPTER 3: RESULTS

Demographics of study subjects

There were 65 subjects in this study; 46 subjects resulted in normal balance performance by BBS, while 19 were discerned with balance deficits and increased fall risk. 45 out of 65 subjects have orthostatic tremor. 23 subjects have primary orthostatic tremor. The majority of the 65 subjects (72.3%) were female and the average age by September 2014 was 69.37 ± 9.508 years old (age range: 32-87 years old). For the normal balance group based on BBS, 29 out of 46 (63.0%) were female and the average age was 68.09 ± 9.793 years old (age range: 32-86 years old). Meanwhile, the mean age of participants with abnormal BBS results was 72.67 ± 8.073 years old (age range: 60-87 years old); 94.7% were female. There was no difference on age distribution between groups (2 independent samples t-test, 2-sided, p=0.083, α=0.05).

Single task analysis

The statistical characteristics of single balance task are listed in Table 4, including sensitivity, specificity, positive predictive value, negative predictive value, positive likelihood ratio, and negative likelihood ratio. Some patients did not complete every balance tests/scales, thus the sample was less than 65 in some tasks, including truncal sway, arising from chair, feet apart eyes closed, feet close eyes open, feet close eyes closed, arm swing, pause after turning, tandem walking, gait in the BARS, pull test and unipodal jump. However, there was no documentation on the original record sheet, so the reason why these data are missing is unknown. It could be due to subjects' refusal of performing those tasks.

High-sensitivity balance tasks (sensitivity ≥ 90%) are stance base, stance with feet apart eyes closed, stance with feet close eyes open, stance with feet close eyes closed, Gait in BARS (0=normal), pull test (0=normal), unipodal jump (both sides 10 jumps=normal). Of note, pull test (0=normal) and unipodal jump (both sides 10 jumps=normal) have sensitivity of 100%.

High-specificity balance tasks (specificity ≥ 90%) are truncal sway, arising from chair and pull test (0 or 1=normal).

Table 4: Statistical characteristics of clinical balance task as compared to Berg Balance Scale

Truncal sway during sit to stand transfer	TP = 7	FP = 3	PPV = 70%
	FN = 11	TN = 40	NPV = 78%
	Sens = 39%	Spec = 93%	PLR = 5.57 NLR = 0.657
Arising from chair (from MDS-UPDRS)	TP = 7	FP = 2	PPV =78%
	FN = 12	TN = 43	NPV = 78%
	Sens = 37%	Spec = 96%	PLR = 8.29 NLR = 0.660
Stance base	TP = 17	FP = 22	PPV = 44%
	FN = 2	TN = 24	NPV = 92%
	Sens = 90%	Spec = 52%	PLR = 1.87 NLR = 0.200
Stance with feet apart eyes closed	TP = 18	FP = 18	PPV = 50%
	FN = 1	TN = 27	NPV = 96%
	Sens = 95%	Spec = 60%	PLR = 2.37 NLR = 0.088
Stance with feet close eyes open	TP = 17	FP = 20	PPV = 46%
	FN = 2	TN = 24	NPV = 92%
	Sens = 90%	Spec = 55%	PLR = 1.97 NLR = 0.193
Stance with feet close eyes closed	TP = 18	FP = 29	PPV = 38%
	FN = 1	TN = 15	NPV = 94%
	Sens = 95%	Spec = 34%	PLR = 1.44 NLR = 0.154
Line of ambulation	TP = 8	FP = 5	PPV = 62%
	FN = 11	TN = 41	NPV = 79%
	Sens = 42%	Spec = 89%	PLR = 3.87 NLR = 0.650
Arm swing in walking	TP = 6	FP = 7	PPV = 46%
	FN = 13	TN = 38	NPV = 75%
	Sens = 32%	Spec = 84%	PLR = 2.03 NLR = 0.810
Pause after turning	TP = 8	FP = 9	PPV = 47%
	FN = 11	TN = 36	NPV = 77%
	Sens = 42%	Spec = 80%	PLR = 2.11 NLR = 0.724
Tip toe walking	TP = 15	FP = 13	PPV = 54%
	FN = 4	TN = 33	NPV = 89%
	Sens = 79%	Spec = 72%	PLR = 2.79 NLR = 0.293

Heel walking	TP = 15	FP = 25	PPV = 38%
	FN = 4	TN = 21	NPV = 84%
	Sens = 79%	Spec = 46%	PLR = 1.45 NLR = 0.461
Tandem walking	TP = 16	FP = 13	PPV = 55%
	FN = 2	TN = 32	NPV = 94%
	Sens = 89%	Spec = 71%	PLR = 3.08 NLR = 0.156
Gait in BARS (≥1)	TP = 18	FP = 18	PPV = 50%
	FN = 1	TN = 27	NPV = 96%
	Sens = 95%	Spec = 60%	PLR = 2.37 NLR = 0.088
Gait in BARS (≥2)	TP = 14	FP = 6	PPV = 70%
	FN = 5	TN = 39	NPV = 89%
	Sens = 74%	Spec = 87%	PLR = 5.53 NLR = 0.304
Pull test (UPDRS ≥1)*	TP = 18	FP = 17	PPV = 51%
	FN = 0	TN = 28	NPV = 100%
	Sens = 100%	Spec = 62%	PLR = 2.65 NLR = 0
Pull test (UPDRS ≥2)	TP = 10	FP = 3	PPV = 77%
	FN = 8	TN = 42	NPV = 84%
	Sens = 56%	Spec = 93%	PLR = 8.33 NLR = 0.476
Pull test (UPDRS ≥3)	TP = 3	FP = 0	PPV = 100%
	FN = 15	TN = 45	NPV = 75%
	Sens = 17%	Spec = 100%	PLR =∞ NLR = 0.833
Unipodal jump (either side ≤2)	TP = 15	FP = 12	PPV = 56%
	FN = 3	TN = 34	NPV = 92%
	Sens = 83%	Spec = 74%	PLR = 3.19 NLR = 0.225
Unipodal jump (both sides ≤2)	TP = 15	FP = 5	PPV = 75%
	FN = 3	TN = 41	NPV = 93%
	Sens = 83%	Spec = 89%	PLR = 7.67 NLR = 0.187
Unipodal jump (either side ≤4)	TP = 16	FP = 17	PPV = 49%
	FN = 2	TN = 29	NPV = 94%
	Sens = 89%	Spec = 63%	PLR = 2.41 NLR = 0.176
Unipodal jump (both sides ≤4)	TP = 16	FP = 11	PPV = 59%
	FN = 2	TN = 35	NPV = 95%
	Sens = 89%	Spec = 76%	PLR = 3.72 NLR = 0.146
Unipodal jump (either side ≤9)	TP = 18	FP = 21	PPV = 46%
	FN = 0	TN = 25	NPV = 100%
	Sens = 100%	Spec = 54%	PLR = 2.19 NLR = 0
Unipodal jump (both sides ≤9)	TP = 16	FP = 15	PPV = 52%
	FN = 2	TN = 31	NPV = 94%
	Sens = 89%	Spec = 67%	PLR = 2.73 NLR = 0.165

**The content between parenthesis marks is the definition of Abnormal.*

A thorough review of each balance task was conducted to form a candidate list for further combined tasks analysis. The gait component from BARS was excluded after reviewing the grading criteria (See Appendix B). The key characters of gait (from BARS) grading are tandem stance, abnormal gait pattern, turn and assistive device, which are redundant to other neurological balance assessment tasks in this study. To be specific, patient with any abnormal arm swing, truncal sway or wide stance base would be graded at 1 or higher in gait from BARS. There is no point to combine two similar tasks to improve accuracy of screening. The tasks with either sensitivity or specificity ≥ 95% were selected as candidates for combined tasks analysis. They are stance with feet apart eyes closed, arising from chair (from UPDRS)[9], pull test and unipodal jump. From the results of single task analysis, you will find both stance with feet apart eyes closed and stance with feet close eyes closed have 95% of sensitivity. The stance with feet close eyes closed are a progression task from feet apart eyes close. The specificity of stance with feet apart eyes closed is 60%; while the specificity of stance with feet close eyes closed is as low as 34%. Thus I included stance with feet apart eyes closed, which has balanced statistical characteristics, into combined tasks analysis.

Combined tasks analysis

Two types of combination were used in this study, “AND” and “OR”. The combination of X AND Y indicates only patients who have positive results of both X and Y tests will be labeled positive; otherwise, they will be labeled negative.

The combination of X OR Y is defined as patients who have a positive result from either X or Y will be labeled with positive. If they are positive in both X and Y tests, patients will be labeled positive; otherwise, patients will be labeled negative.

All the statistical characteristics of the attempted combination are listed in table 5. The content between parenthesis marks is the definition of abnormal. Multiple cutoff points were used for the pull test and unipodal jump. There is a tendency that OR combination boosts sensitivity but sacrifices specificity; AND combination decreases sensitivity but increases specificity.

The combination of unipodal jump (both sides ≤2) OR Pull test (≥2) has 89% sensitivity and 83% specificity. The combination of unipodal jump (both sides ≤2) OR arising of UPDRS has 83% sensitivity and 84% specificity. For the rest combinations, either sensitivity or specificity is sacrificed to some extent. A test or scale with both sensitivity and specificity over 80% will be fair enough to predict non-fatal medical end points, such as falls.

Table 5: Statistical characteristics of combined clinical tests as compared to Berg Balance Scale

Unipodal jump (both sides ≤2)* **OR** Pull test (≥1)	TP = 18	FP = 20	PPV = 47%
	FN = 0	TN = 26	NPV = 100%
	Sens = 100%	Spec = 57%	PLR = 2.30 NLR = 0
Unipodal jump (both sides ≤2) **AND** Pull test (≥1)	TP = 15	FP = 2	PPV =88%
	FN = 4	TN = 43	NPV = 92%
	Sens = 79%	Spec = 96%	PLR = 17.8 NLR = 0.220
Unipodal jump (both sides ≤2) **OR** Pull test (≥2)	TP = 16	FP = 8	PPV = 67%
	FN = 2	TN = 38	NPV = 95%
	Sens = 89%	Spec = 83%	PLR = 5.11 NLR = 0.135
Unipodal jump (both sides ≤2) **AND** Pull test (≥2)	TP = 9	FP = 0	PPV = 100%
	FN = 8	TN = 45	NPV = 85%
	Sens = 53%	Spec = 100%	PLR = ∞ NLR = 0.471
Unipodal jump (both sides ≤2) **AND** Arising of UPDRS	TP = 7	FP = 0	PPV = 100%
	FN = 12	TN = 46	NPV = 79%
	Sens =37%	Spec = 100%	PLR = ∞ NLR = 0.632
Unipodal jump (both sides ≤2) **OR** Arising of UPDRS	TP = 15	FP = 7	PPV = 68%
	FN = 3	TN = 38	NPV = 93%
	Sens =83%	Spec = 84%	PLR =5.36 NLR = 0.197
Unipodal jump (either side ≤9) **AND** Feet apart eyes closed	TP = 17	FP = 12	PPV = 59%
	FN = 1	TN = 34	NPV = 97%
	Sens =94%	Spec = 74%	PLR = 3.62 NLR = 0.075

**The content between parenthesis marks is the definition of Abnormal*

CHAPTER 4: DISCUSSION

The critical character to determine a good screening tool is to use negative likelihood ratio (NLR).[4] $NLR = \frac{1-sensitivity}{specificity}$. From mathematical standpoint, we are looking for something with high sensitivity and high specificity to pursue the NLR as close to 0 as possible. But in most cases, high sensitivity and high specificity are mutually exclusive. For example, loosening a cutoff increases the sensitivity but decreases specificity. If a screening tool whose specificity is lower than 50%, it would not be a good screening tool even though the sensitivity is perfect. Specificity less than 50% means the capability to detect true negative is less than tossing a coin, which is 50/50. Thus, it is critical to choose a screening tool with balanced sensitivity and specificity.

This study is highly clinically relevant to focus on concurrent validity of neurological balance assessment, using functional balance scale as gold standard. The statistical characteristics of neurological tasks to assess fall risk is unknown. In this study, those of which sensitivity over 95% are good tests to consider in screening process, including stance with feet apart eyes closed, stance with feet close eyes closed, gait from BARS (0=normal), pull test (0=normal), unipodal jump (both sides reach 10 times=normal). Single use of them could promisingly capture 95% of true population who has fall risk, regardless of false positive. But as a screening tool to assess fall risk, clinical practitioner would be compromised with false positive instead of false negative if they have to choose one. For those patients in false positive group, there is no harm because no invasive procedure will be followed after detecting fall risk. In contrast, those people in false negative group may be negatively affected. They may receive less medical attention of fall prevention, leading to a fall and fall related injuries. Thus, it is acceptable to sacrifice the specificity of screening tool and rule in all the potential fallers instead of missing patients with fall risk.

Of all the sensitive tasks, the pull test and unipodal jump are of the most clinical importance. It is hard for patients with fear of falling to participate in or try their best in the stance task with eyes closed, which impeding the capability of these tasks to differentiate the true fall risk versus patients' self-limitation. The gait component from the BARS is specific to ataxia and the ceiling effect of the test might influence the result. Unipodal jump is a task that not commonly used in elderly population because of its high demand on strength, coordination and balance. However, it will be an excellent screening tool for people with high physical function and also acts as a supplement to other tasks with ceiling effect.

In order to achieve a balanced sensitivity and specificity, combined tasks analysis was conducted from a list of candidate single tasks in this study. It is possible that the combination of two tasks with fair sensitivity actually could become a good screening tool. For example, if task A captures 50% of true positive and task B captures the other 50%, the combination of A OR B will be 100% of sensitivity. However, the likelihood of such situation is very low based on clinical situations with diversity or between subjects' variations. The combination method in this study provides an idea for clinical practitioners what other tasks they can perform if patient is slightly abnormal on one task. For example, pull test ($\geq$2 as cutoff) by itself has 56% of sensitivity and 93% of specificity. But the combination of unipodal jump (both sides $\leq$2) OR pull test ($\geq$2) has 89% of sensitivity and 83% of specificity. If a patient takes 3-5 steps to catch balance in pull test, which will be graded as 1 by pull test grading criteria, clinical practitioners can ask them to jump on one leg and see whether they can single leg hop 3 times on either leg. Interestingly, the NLR of pull test ($\geq$2 as cutoff) as single task screening is the same as that of the combination, which is 0.135.

The combination of unipodal jump (either side ≤9 as abnormal) AND feet apart eyes closed has best NLR among all attempted combinations, which is 0.075. To interpret, if there is a patient who can stand with feet apart eyes closed but unable to single leg hop 10 times on neither leg, clinical practitioners are still confident to state that the his/her risk of falling is low.

The limitation of this study is that it is a secondary study based on a dataset of orthostatic tremor patients and their spouses. Subjects diagnosed with vestibular disease or at a high risk of falling were excluded due to intolerance of tasks, thus the study of this results cannot be extended to general population prone to fall. In contrast, patient with POT rarely falls and their spousal controls are not frequent fallers, therefore the results of this study can be applied to the population without a frequent history of fall. As a methodological study, the sample size is relatively small and age distribution is not normally distributed. It may more likely applicable to elderly population since the mean age of subjects is over 65 years old.

There are not many studies on the statistical characteristics or parameters of neurological balance assessments. Therefore, further studies in general population should be followed, especially on pull test and unipodal jump.

CHAPTER 5: CONCLUSION

In this study, a number of single tasks of neurological balance assessment can screen fall risk with sensitivity ≥90%. They are stance base, stance with feet apart eyes closed, stance with feet close eyes open, stance with feet close eyes closed, Gait in BARS (0=normal), pull test (0=normal), unipodal jump (both sides 10 jumps=normal). The pull test and unipodal jump are of the most clinical importance. The pull test can be used in general patients encountered in the clinic, while unipodal jump is for high-function patients.

For the combined tasks of neurological balance assessment, both combined unipodal jump (both sides ≤2) OR Pull test (≥2) and combined unipodal jump (both sides ≤2) OR arising of UPDRS (≥1) increase the specificity of screening method.

Reference List:

1. WHO global report on falls prevention in older age. https://www.who.int/violence_injury_prevention/publications/other_injury/falls_prevention.pdf?ua=1. Updated 2007. Accessed 04/05, 2019.

2. Older adult falls. https://www.cdc.gov/features/falls-older-adults/index.html. Updated 2018. Accessed 04/05, 2019.

3. Gordis L. *Epidemiology.* Philadelphia: Elsevier; 2014.

4. McGee S. Simplifying likelihood ratios. *J Gen Intern Med*. 2002;17(8):646-649.

5. Berg KO, Wood-Dauphinee SL, Williams JI, Maki B. Measuring balance in the elderly: Validation of an instrument. *Can J Public Health*. 1992;83 Suppl 2:S7-11.

6. Berg KO, Maki BE, Williams JI, Holliday PJ, Wood-Dauphinee SL. Clinical and laboratory measures of postural balance in an elderly population. *Arch Phys Med Rehabil*. 1992;73(11):1073-1080.

7. Lajoie Y, Gallagher SP. Predicting falls within the elderly community: Comparison of postural sway, reaction time, the berg balance scale and the activities-specific balance confidence (ABC) scale for comparing fallers and non-fallers. *Arch Gerontol Geriatr*. 2004;38(1):11-26.

8. Stevenson TJ. Detecting change in patients with stroke using the berg balance scale. *Aust J Physiother*. 2001;47(1):29-38.

9. Goetz CG, Tilley BC, Shaftman SR, et al. Movement disorder society-sponsored revision of the unified parkinson's disease rating scale (MDS-UPDRS): Scale presentation and clinimetric testing results. *Mov Disord*. 2008;23(15):2129-2170.

10. Duncan PW, Weiner DK, Chandler J, Studenski S. Functional reach: A new clinical measure of balance. *J Gerontol*. 1990;45(6):M192-7.

11. Duncan PW, Studenski S, Chandler J, Prescott B. Functional reach: Predictive validity in a sample of elderly male veterans. *J Gerontol*. 1992;47(3):M93-8.

12. Shumway-Cook A, Woollacott M. *Motor control: Theory and practical applications.* Baltimore: Md:Williams & Wilkins; 1995.

13. Wrisley DM, Marchetti GF, Kuharsky DK, Whitney SL. Reliability, internal consistency, and validity of data obtained with the functional gait assessment. *Phys Ther*. 2004;84(10):906-918.

14. Chiu YP, Fritz SL, Light KE, Velozo CA. Use of item response analysis to investigate measurement properties and clinical validity of data for the dynamic gait index. *Phys Ther*. 2006;86(6):778-787.

15. Wrisley DM, Kumar NA. Functional gait assessment: Concurrent, discriminative, and predictive validity in community-dwelling older adults. *Phys Ther*. 2010;90(5):761-773.

16. Shumway-Cook A, Brauer S, Woollacott M. Predicting the probability for falls in community-dwelling older adults using the timed up & go test. *Phys Ther*. 2000;80(9):896-903.

17. Whitney JC, Lord SR, Close JC. Streamlining assessment and intervention in a falls clinic using the timed up and go test and physiological profile assessments. *Age Ageing*. 2005;34(6):567-571.

18. Munhoz RP, Li JY, Kurtinecz M, et al. Evaluation of the pull test technique in assessing postural instability in parkinson's disease. *Neurology*. 2004;62(1):125-127.

19. Bloem BR, Beckley DJ, van Hilten BJ, Roos RA. Clinimetrics of postural instability in parkinson's disease. *J Neurol*. 1998;245(10):669-673.

20. Morita H, Hass CJ, Moro E, Sudhyadhom A, Kumar R, Okun MS. Pedunculopontine nucleus stimulation: Where are we now and what needs to be done to move the field forward? *Front Neurol*. 2014;5:243.

21. Thevathasan W, Coyne TJ, Hyam JA, et al. Pedunculopontine nucleus stimulation improves gait freezing in parkinson disease. *Neurosurgery*. 2011;69(6):1248-53; discussion 1254.

22. Heilman KM. Orthostatic tremor. *Arch Neurol*. 1984;41(8):880-881.

23. Bhatia KP, Bain P, Bajaj N, et al. Consensus statement on the classification of tremors. from the task force on tremor of the international parkinson and movement disorder society. *Mov Disord*. 2018;33(1):75-87.

24. Britton TC, Thompson PD, van der Kamp W, et al. Primary orthostatic tremor: Further observations in six cases. *J Neurol*. 1992;239(4):209-217.

25. Fung VS, Sauner D, Day BL. A dissociation between subjective and objective unsteadiness in primary orthostatic tremor. *Brain*. 2001;124(Pt 2):322-330.

26. McAuley JH, Britton TC, Rothwell JC, Findley LJ, Marsden CD. The timing of primary orthostatic tremor bursts has a task-specific plasticity. *Brain*. 2000;123 (Pt 2)(Pt 2):254-266.

27. Manrique-Huarte R, Arcocha J, Perez-Fernandez N. Orthostatic tremor inducing instability. *Acta Otorrinolaringol Esp*. 2012;63(2):120-124.

28. Bacsi AM, Fung VS, Colebatch JG. Sway patterns in orthostatic tremor: Impairment of postural control mechanisms. *Mov Disord*. 2005;20(11):1469-1475.

29. Manrique-Huarte R, Arcocha J, Perez-Fernandez N. Orthostatic tremor inducing instability. *Acta Otorrinolaringol Esp*. 2012;63(2):120-124.

30. Sharott A, Marsden J, Brown P. Primary orthostatic tremor is an exaggeration of a physiological response to instability. *Mov Disord*. 2003;18(2):195-199.

31. Wuehr M, Schlick C, Mohwald K, Schniepp R. Proprioceptive muscle tendon stimulation reduces symptoms in primary orthostatic tremor. *J Neurol*. 2018.

32. Schoberl F, Feil K, Xiong G, et al. Pathological ponto-cerebello-thalamo-cortical activations in primary orthostatic tremor during lying and stance. *Brain*. 2017;140(1):83-97.

33. Bhatti D, Thompson R, Xia Y, et al. Comprehensive, blinded assessment of balance in orthostatic tremor. *Parkinsonism Relat Disord*. 2018;47:22-25.

34. Claesson IM, Grooten WJ, Lokk J, Stahle A. Assessing postural balance in early parkinson's disease-validity of the BDL balance scale. *Physiother Theory Pract*. 2017;33(6):490-496.

35. Keune PM, Young WR, Paraskevopoulos IT, et al. Measuring standing balance in multiple sclerosis: Further progress towards an automatic and reliable method in clinical practice. *J Neurol Sci*. 2017;379:157-162.

36. Mong Y, Teo TW, Ng SS. 5-repetition sit-to-stand test in subjects with chronic stroke: Reliability and validity. *Arch Phys Med Rehabil*. 2010;91(3):407-413.

37. Ng SSM, Tse MMY, Tam EWC, Lai CYY. Reliability and convergent validity of the five-step test in people with chronic stroke. *J Rehabil Med*. 2018;50(1):16-21.

38. Nilsagard Y, Carling A, Davidsson O, Franzen L, Forsberg A. Comparison of trunk impairment scale versions 1.0 and 2.0 in people with multiple sclerosis: A validation study. *Physiother Theory Pract*. 2017;33(10):772-779.

39. Song JW, Kim JM, Cheong YS, et al. Balance assessment in subacute stroke patients using the balance control trainer (BalPro). *Ann Rehabil Med*. 2017;41(2):188-196.

40. Zur O, Shaki T, Carmeli E. Concurrent validity and reliability of a new balance scale used in older adults. *Adv Exp Med Biol*. 2016;910:63-70.

Appendix A

Berg Balance Scale

The Berg Balance Scale (BBS) was developed to measure balance among older people with impairment in balance function by assessing the performance of functional tasks. It is a valid instrument used for evaluation of the effectiveness of interventions and for quantitative descriptions of function in clinical practice and research. The BBS has been evaluated in several reliability studies. *A recent study of the BBS, which was completed in Finland, indicates that a change of eight (8) BBS points is required to reveal a genuine change in function between two assessments among older people who are dependent in ADL and living in residential care facilities.*

Description:
14-item scale designed to measure balance of the older adult in a clinical setting.

Equipment needed: Ruler, two standard chairs (one with arm rests, one without), footstool or step, stopwatch or wristwatch, 15 ft walkway

Completion:
Time: 15-20 minutes
Scoring: A five-point scale, ranging from 0-4. "0" indicates the lowest level of function and "4" the highest level of function. Total Score = 56

Interpretation: 41-56 = low fall risk
21-40 = medium fall risk
0 –20 = high fall risk

A change of 8 points is required to reveal a genuine change in function between 2 assessments.

Berg Balance Scale

Name: ___________________________________ Date: ____________________

Location: _________________________________ Rater: ____________________

ITEM DESCRIPTION	SCORE (0-4)
Sitting to standing	________
Standing unsupported	________
Sitting unsupported	________
Standing to sitting	________
Transfers	________
Standing with eyes closed	________
Standing with feet together	________
Reaching forward with outstretched arm	________
Retrieving object from floor	________
Turning to look behind	________
Turning 360 degrees	________
Placing alternate foot on stool	________
Standing with one foot in front	________
Standing on one foot	________

Total ________

GENERAL INSTRUCTIONS
Please document each task and/or give instructions as written. When scoring, please record the lowest response category that applies for each item.

In most items, the subject is asked to maintain a given position for a specific time. Progressively more points are deducted if:

- the time or distance requirements are not met
- the subject's performance warrants supervision
- the subject touches an external support or receives assistance from the examiner

Subject should understand that they must maintain their balance while attempting the tasks. The choices of which leg to stand on or how far to reach are left to the subject. Poor judgment will adversely influence the performance and the scoring.

Equipment required for testing is a stopwatch or watch with a second hand, and a ruler or other indicator of 2, 5, and 10 inches. Chairs used during testing should be a reasonable height. Either a step or a stool of average step height may be used for item # 12.

Berg Balance Scale

SITTING TO STANDING
INSTRUCTIONS: Please stand up. Try not to use your hand for support.
( ) 4 able to stand without using hands and stabilize independently
( ) 3 able to stand independently using hands
( ) 2 able to stand using hands after several tries
( ) 1 needs minimal aid to stand or stabilize
( ) 0 needs moderate or maximal assist to stand

STANDING UNSUPPORTED
INSTRUCTIONS: Please stand for two minutes without holding on.
( ) 4 able to stand safely for 2 minutes
( ) 3 able to stand 2 minutes with supervision
( ) 2 able to stand 30 seconds unsupported
( ) 1 needs several tries to stand 30 seconds unsupported
( ) 0 unable to stand 30 seconds unsupported

If a subject is able to stand 2 minutes unsupported, score full points for sitting unsupported. Proceed to item #4.

SITTING WITH BACK UNSUPPORTED BUT FEET SUPPORTED ON FLOOR OR ON A STOOL
INSTRUCTIONS: Please sit with arms folded for 2 minutes.
( ) 4 able to sit safely and securely for 2 minutes
( ) 3 able to sit 2 minutes under supervision
( ) 2 able to able to sit 30 seconds
( ) 1 able to sit 10 seconds
( ) 0 unable to sit without support 10 seconds

STANDING TO SITTING
INSTRUCTIONS: Please sit down.
( ) 4 sits safely with minimal use of hands
( ) 3 controls descent by using hands
( ) 2 uses back of legs against chair to control descent
( ) 1 sits independently but has uncontrolled descent
( ) 0 needs assist to sit

TRANSFERS
INSTRUCTIONS: Arrange chair(s) for pivot transfer. Ask subject to transfer one way toward a seat with armrests and one way toward a seat without armrests. You may use two chairs (one with and one without armrests) or a bed and a chair.
( ) 4 able to transfer safely with minor use of hands
( ) 3 able to transfer safely definite need of hands
( ) 2 able to transfer with verbal cuing and/or supervision
( ) 1 needs one person to assist
( ) 0 needs two people to assist or supervise to be safe

STANDING UNSUPPORTED WITH EYES CLOSED
INSTRUCTIONS: Please close your eyes and stand still for 10 seconds.
( ) 4 able to stand 10 seconds safely
( ) 3 able to stand 10 seconds with supervision
( ) 2 able to stand 3 seconds
( ) 1 unable to keep eyes closed 3 seconds but stays safely
( ) 0 needs help to keep from falling

STANDING UNSUPPORTED WITH FEET TOGETHER
INSTRUCTIONS: Place your feet together and stand without holding on.
( ) 4 able to place feet together independently and stand 1 minute safely
( ) 3 able to place feet together independently and stand 1 minute with supervision
( ) 2 able to place feet together independently but unable to hold for 30 seconds
( ) 1 needs help to attain position but able to stand 15 seconds feet together
( ) 0 needs help to attain position and unable to hold for 15 seconds

Berg Balance Scale continued…

REACHING FORWARD WITH OUTSTRETCHED ARM WHILE STANDING
INSTRUCTIONS: Lift arm to 90 degrees. Stretch out your fingers and reach forward as far as you can. (Examiner places a ruler at the end of fingertips when arm is at 90 degrees. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the fingers reach while the subject is in the most forward lean position. When possible, ask subject to use both arms when reaching to avoid rotation of the trunk.)
( ) 4 can reach forward confidently 25 cm (10 inches)
( ) 3 can reach forward 12 cm (5 inches)
( ) 2 can reach forward 5 cm (2 inches)
( ) 1 reaches forward but needs supervision
( ) 0 loses balance while trying/requires external support

PICK UP OBJECT FROM THE FLOOR FROM A STANDING POSITION
INSTRUCTIONS: Pick up the shoe/slipper, which is in front of your feet.
( ) 4 able to pick up slipper safely and easily
( ) 3 able to pick up slipper but needs supervision
( ) 2 unable to pick up but reaches 2-5 cm(1-2 inches) from slipper and keeps balance independently
( ) 1 unable to pick up and needs supervision while trying
( ) 0 unable to try/needs assist to keep from losing balance or falling

TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDERS WHILE STANDING
INSTRUCTIONS: Turn to look directly behind you over toward the left shoulder. Repeat to the right. (Examiner may pick an object to look at directly behind the subject to encourage a better twist turn.)
( ) 4 looks behind from both sides and weight shifts well
( ) 3 looks behind one side only other side shows less weight shift
( ) 2 turns sideways only but maintains balance
( ) 1 needs supervision when turning
( ) 0 needs assist to keep from losing balance or falling

TURN 360 DEGREES
INSTRUCTIONS: Turn completely around in a full circle. Pause. Then turn a full circle in the other direction.
( ) 4 able to turn 360 degrees safely in 4 seconds or less
( ) 3 able to turn 360 degrees safely one side only 4 seconds or less
( ) 2 able to turn 360 degrees safely but slowly
( ) 1 needs close supervision or verbal cuing
( ) 0 needs assistance while turning

PLACE ALTERNATE FOOT ON STEP OR STOOL WHILE STANDING UNSUPPORTED
INSTRUCTIONS: Place each foot alternately on the step/stool. Continue until each foot has touched the step/stool four times.
( ) 4 able to stand independently and safely and complete 8 steps in 20 seconds
( ) 3 able to stand independently and complete 8 steps in > 20 seconds
( ) 2 able to complete 4 steps without aid with supervision
( ) 1 able to complete > 2 steps needs minimal assist
( ) 0 needs assistance to keep from falling/unable to try

STANDING UNSUPPORTED ONE FOOT IN FRONT
INSTRUCTIONS: (DEMONSTRATE TO SUBJECT) Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. (To score 3 points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject's normal stride width.)
( ) 4 able to place foot tandem independently and hold 30 seconds
( ) 3 able to place foot ahead independently and hold 30 seconds
( ) 2 able to take small step independently and hold 30 seconds
( ) 1 needs help to step but can hold 15 seconds
( ) 0 loses balance while stepping or standing

STANDING ON ONE LEG
INSTRUCTIONS: Stand on one leg as long as you can without holding on.
( ) 4 able to lift leg independently and hold > 10 seconds
( ) 3 able to lift leg independently and hold 5-10 seconds
( ) 2 able to lift leg independently and hold ≥ 3 seconds
( ) 1 tries to lift leg unable to hold 3 seconds but remains standing independently.
( ) 0 unable to try of needs assist to prevent fall

( ) TOTAL SCORE (Maximum = 56)

Appendix B

"Arising from chair" from UPDRS

3.9 ARISING FROM CHAIR

Instructions to examiner: Have the patient sit in a straight-backed chair with arms, with both feet on the floor and sitting back in the chair (if the patient is not too short). Ask the patient to cross his/her arms across the chest and then to stand up. If the patient is not successful, repeat this attempt a maximum up to two more times. If still unsuccessful, allow the patient to move forward in the chair to arise with arms folded across the chest. Allow only one attempt in this situation. If unsuccessful, allow the patient to push off using his/her hands on the arms of the chair. Allow a maximum of three trials of pushing off. If still not successful, assist the patient to arise. After the patient stands up, observe the posture for item 3.13

0:	Normal:	No problems. Able to arise quickly without hesitation.
1:	Slight:	Arising is slower than normal; or may need more than one attempt; or may need to move forward in the chair to arise. No need to use the arms of the chair.
2:	Mild:	Pushes self up from arms of chair without difficulty.
3:	Moderate:	Needs to push off, but tends to fall back; or may have to try more than one time using arms of chair, but can get up without help.
4:	Severe:	Unable to arise without help.

"Pull test", as known as postural stability assessment from MDS-UPDRS

3.12 POSTURAL STABILITY

Instructions to examiner: The test examines the response to sudden body displacement produced by a quick, forceful pull on the shoulders while the patient is standing erect with eyes open and feet comfortably apart and parallel to each other. Test retropulsion. Stand behind the patient and instruct the patient on what is about to happen. Explain that s/he is allowed to take a step backwards to avoid falling. There should be a solid wall behind the examiner, at least 1-2 meters away to allow for the observation of the number of retropulsive steps. The first pull is an instructional demonstration and is purposely milder and not rated. The second time the shoulders are pulled briskly and forcefully towards the examiner with enough force to displace the center of gravity so that patient MUST take a step backwards. The examiner needs to be ready to catch the patient, but must stand sufficiently back so as to allow enough room for the patient to take several steps to recover independently. Do not allow the patient to flex the body abnormally forward in anticipation of the pull. Observe for the number of steps backwards or falling. Up to and including two steps for recovery is considered normal, so abnormal ratings begin with three steps. If the patient fails to understand the test, the examiner can repeat the test so that the rating is based on an assessment that the examiner feels reflects the patient's limitations rather than misunderstanding or lack of preparedness. Observe standing posture for item 3.13

0:	Normal:	No problems: Recovers with one or two steps.
1:	Slight:	3-5 steps, but subject recovers unaided.
2:	Mild:	More than 5 steps, but subject recovers unaided.
3:	Moderate:	Stands safely, but with absence of postural response; falls if not caught by examiner.
4:	Severe:	Very unstable, tends to lose balance spontaneously or with just a gentle pull on the shoulders.

"Gait" assessment from Brief Ataxia Rate Scale (BARS)

Gait

0: Normal

1: Almost normal naturally, but unable to walk with feet in tandem position

2: Walking without support, but clearly abnormal and irregular

3: Walking without support but with considerable staggering; difficulties in half turn

4: Walking without support not possible; uses support of the wall for 10-meter test.

5: Walking possible only with one cane

6: Walking possible only with two canes or with a stroller

7: Walking possible only with one accompanying person

8: Walking impossible with one accompanying person (2-person assist; wheelchair)

Appendix C

Neurological exam worksheet used by neurologists in OT study

NEUROLOGICAL EXAMINATION

Accelerometric Recording (with comments below):				Tremor Frequency	Tremor Amplitude:	
Frontal "release" signs:			Normal	Abnormal (how many?)		
Test for 1. Glabellar tap, 2. Palmomental reflex 3. Snout reflex. 4. Grasp Reflex						
Ocular movements: (check for following) ma						
Square wave jerks		Present	Absent			
Nystagmus		Present	Absent			
Visual persistence		Normal	Abnormal			
Saccade initiation		Normal	Abnormal			
Saccade speed		Normal	Abnormal (slow)			
Facial strength: (check for sm						
Hearing was evaluated using		CALFRAST		Normal Soft 70		
		Abnormal Strong 70		Abnormal Soft35	Abnormal Strong35	Worse than 35
Dysarthria:		Present	Absent	UPDRS Score		
Tone:		UPDRS Score	RUE	LUE		
UPDRS Fniger taps			RUE	LUE		
Bradykinesia: (UPDRS) hand open and close			RUE	LUE		
	UPDRS Hand twist and turn		RUE	LUE		
Tremor (score per UPDRS where possible)						
Resting tremor			RUE	LUE		
Postural tremo	Hand extended		RUE	LUE		
	Hand close to body		RUE	LUE		
	Leg stretched out		RLE	LLE		
Action tremor	Hand open and close		RUE	LUE		
	Foot up and down at ankle		RUE	LUE		
Intention Trem	(score in BARS)		RUE	LUE		
Coordination: (test components below and score as normal or abnormal)						
Finger-to-nose:			Normal	Abnormal		
Rapid alternating hand movements:			Normal	Abnormal		
Finger-following-finger:			Normal	Abnormal		
Sequential finger movements:			Normal	Abnormal		
Hand rhythm tapping:			Normal	Abnormal		
Heel-to knee-shin:			Normal	Abnormal		
Toe-following-finger:			Normal	Abnormal		
Gait:						

Truncal sway or titubation while sitting/raisir	Present	Absent	
Raising per UPDRS	Score 0-4		
Stance base	Normal	Wide	
Stance with feet apart, eyes closed.	Normal	Abnormal (truncal sway, unable to do or near fall)	
Stance with feet close to each other, eyes op	Normal	Abnormal	
Stance with feet close to each other, eyes cl	Normal	Abnormal	
Posture (as per UPDRS)	Score 0-4		
Line of ambulation	Straight	Wavy	
Arm swing	Present	Absent	
Pause after turning	Present	Absent	
Tip toe walking	Normal	Abnormal (Wide base, wavy gait line, side stepping)	
Heels walking	Normal	Abnormal (Wide base, wavy gait line, side stepping)	
Tandem walking	Normal	Abnormal (more than 1 side step in 10 step walking)	
Right foot jump in place - number of jumps without falling (up to 10)			
Left foot jump in place - number of jumps without falling (up to 10)			
Pull test (as per UPDRS)	Score 0-4		

BARS Total Score

Gait

0: Normal

Gait SCORE

1: Almost normal naturally, but unable to walk with feet in tandem position

2: Walking without support, but clearly abnormal and irregular

3: Walking without support but with considerable staggering; difficulties in half turn

4: Walking without support not possible; uses support of the wall for 10-meter test.

5: Walking possible only with one cane

6: Walking possible only with two canes or with a stroller

7: Walking possible only with one accompanying person

8: Walking impossible with one accompanying person (2-person assist; wheelchair)

Knee-tibia test (decomposition of movement and intention tremor)

(Left and Right scored)
0: Normal
1: Lowering of heel in continuous axis, but movement is decomposed in several phases, without real jerks, or abnormally slow
2: Lowering jerkily in the axis
3: Lowering jerkily with lateral movements
4: Lowering jerkily with extremely long lateral movements, or test impossible

HKS SCORE
RIGHT
LEFT

Finger-to-nose test (decomposition and dysmetria of arm and hand)
(Left and Right scored)
0: Normal
1: Oscillating movement of arm and/or hand without decomposition of the movement
2: Segmented movement in 2 phases and / or moderate dysmetria in reaching nose
3: Segmented movement in more than 2 phases and / or considerable dysmetria in reaching nose
4: Dysmetria preventing the patient from reaching nose

FNF SCORE
RIGHT
LEFT

Dysarthria
0: Normal
1: Mild impairment of rate/rhythm/clarity
2: Moderate impairment of rate/rhythm/clarity
3: Severely slow and dysarthric speech
4: Speech absent or unintelligible

Speech SCORE

Oculomotor abnormalities
0: Normal
1: Slightly slowed pursuit, saccadic intrusions, hypo/hypermetric saccade, nystagmus
2: Prominently slowed pursuit, saccadic intrusions, hypo/ hypermetric saccade, nystagmus

EOM SCORE